



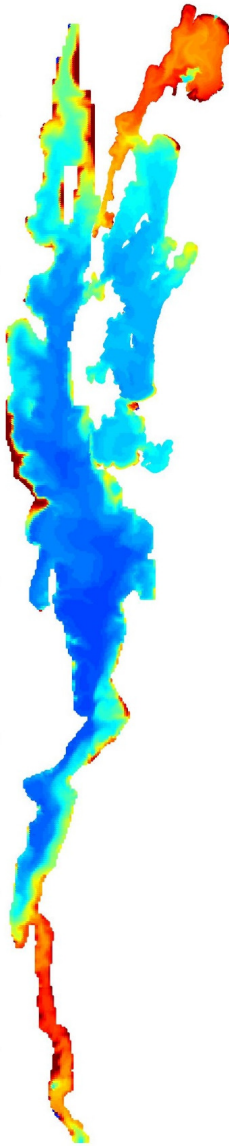
# Causeways and Circulation in Lake Champlain

Liv Herdman, USGS NYWSC  
Tom Manley, Peter Mehler from Middlebury College  
Herman Kernkamp, Deltares

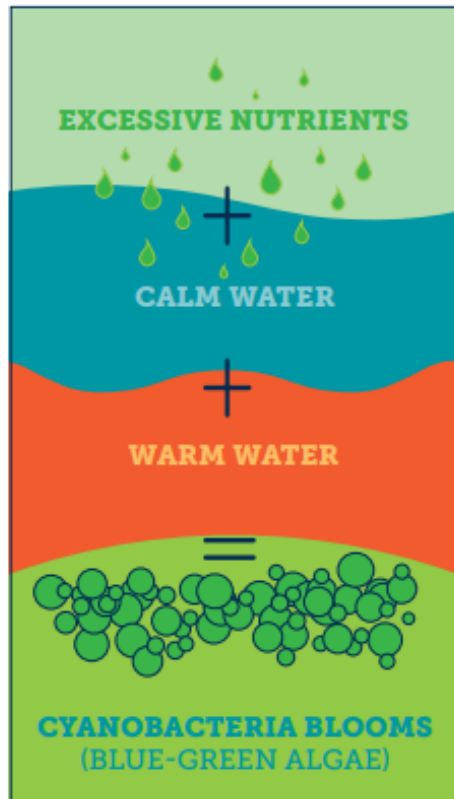
Presented to International Association of Great Lakes Research  
Brockport, New York  
June, 2019

U.S. Department of the Interior  
U.S. Geological Survey

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# Cyanobacteria blooms are an increasingly persistent problem



*Cyanobacteria blooms can limit the use of beaches on Lake Champlain. Photo: LCBP.*

# 12 beaches were closed due to cyanobacterial blooms in the last 3 years

Lake Champlain Basin Program State of the Lake 2018



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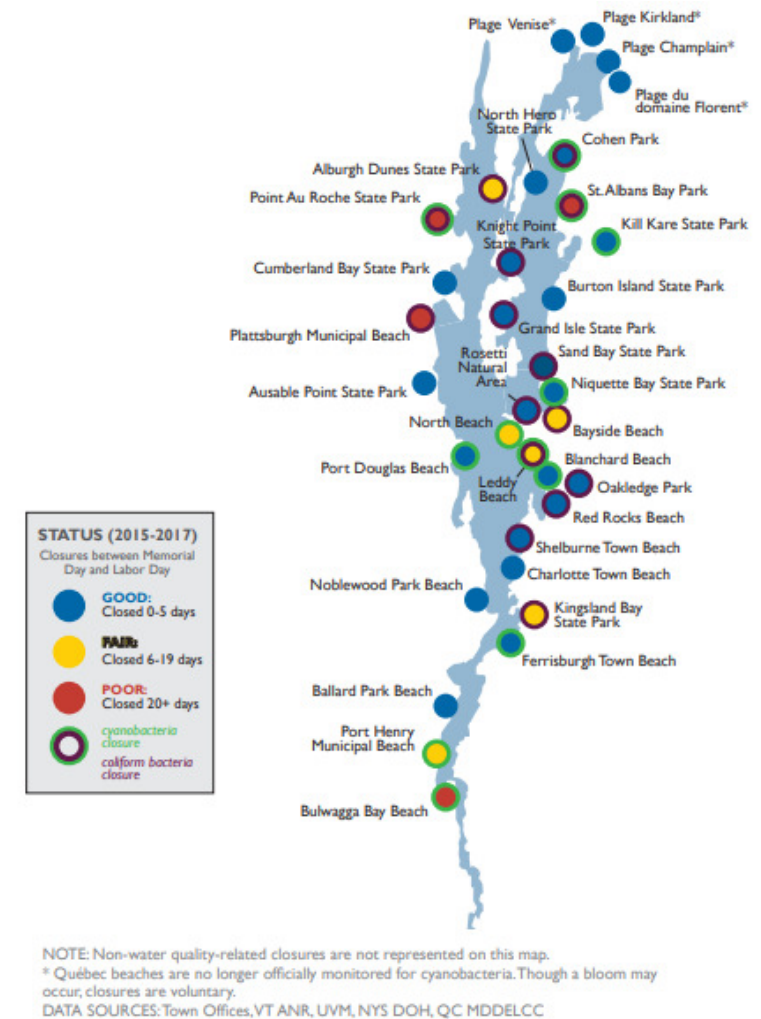


Figure 2 | Public beach closures on Lake Champlain, 2015–2017

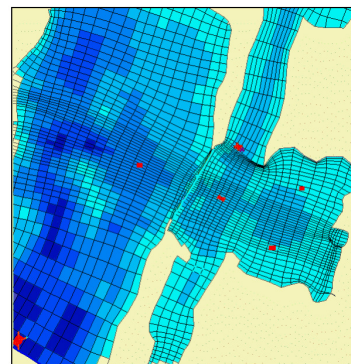
The Public and Residents of Shoreline Communities often blame causeways

# North Hero Town Plan 2009

Adopted by the North Hero Selectboard  
November 16, 2009



Several efforts are underway to address water quality in Lake Champlain, which will have an impact on water quality along North Hero's shorelines. Vermont has adopted, along with Quebec and New York, a plan for reducing phosphorus in Lake Champlain. In addition, the Department of Environmental Conservation is coordinating watershed planning efforts with the Clean and Clear Plan for Northern Lake Champlain. Efforts are also underway to restore some of the natural flow to Lake Champlain by removing causeways, such as the Carry Bay causeway in North Hero.



**Carry Bay Causeway**  
A Field Study and Hydrodynamic Model

Prepared for the Vermont Department of Environmental Conservation — January 2004

BINKERD ENVIRONMENTAL Inc

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# The Public and Residents of Shoreline Communities often blame causeways

## Causeway frustrates Lake Champlain cleanup

Joel Banner Baird, Free Press Staff Writer Published 6:02 a.m. ET April 3, 2017



Many water-quality advocates say the stagnant Missisquoi Bay needs better circulation — but rare, spiny softshell turtles love the stone causeway at the bay's mouth. JOEL BANNER BAIRD/FREE PRESS

## VTrans proposes removing portion of bay causeway

Project would cost \$2 million

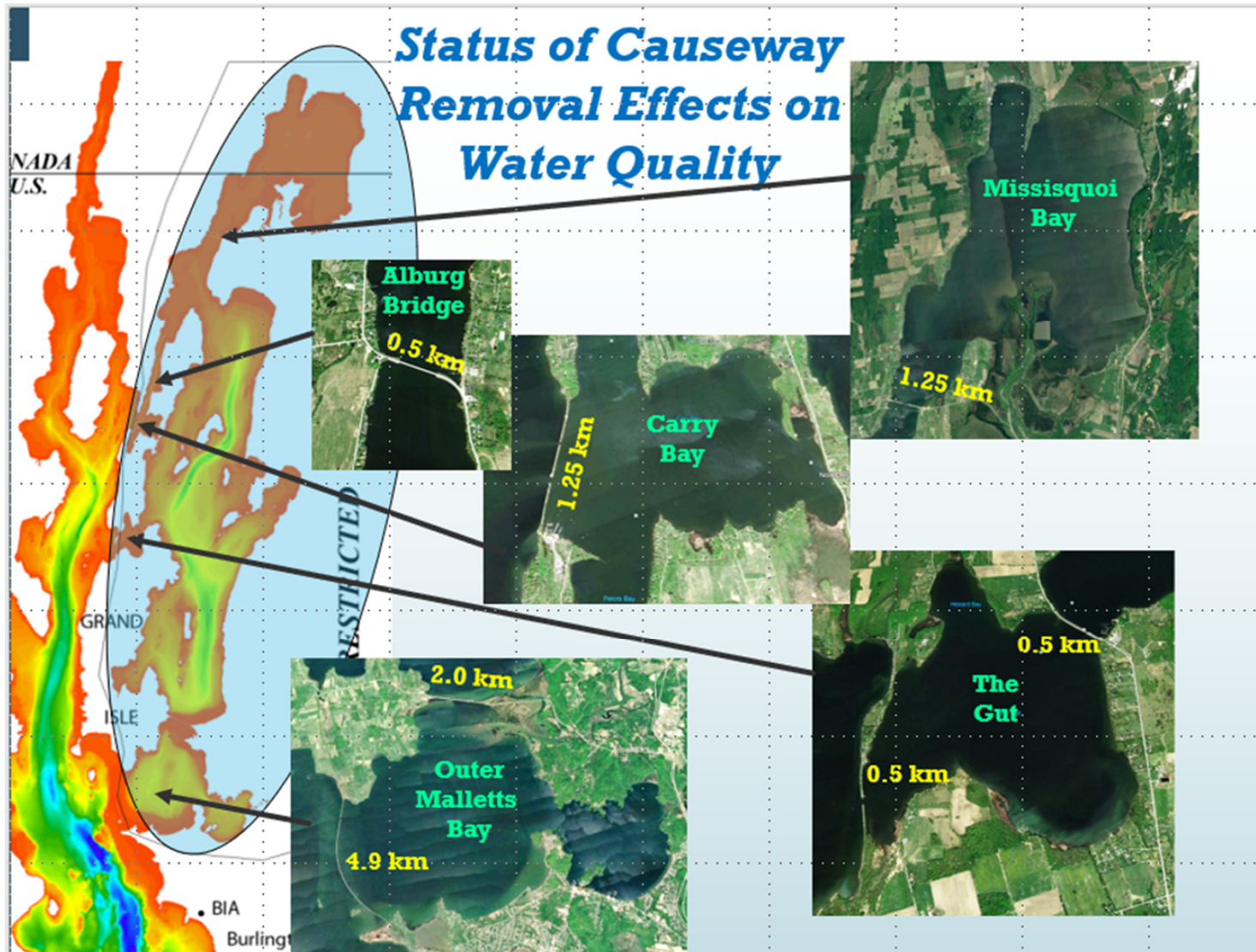
Posted by Michelle Monroe | Feb 13, 2017 | News, Showcase News | 0 | ★★★★★



*This map from VTrans shows the location of the remaining causeway.*



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# Questions

- How do the causeways change the circulation in the Lake?
- Can removal of the causeways reduce residence time or reduce temperature in affected portions of the lake?
- How has causeway placement changed the morphology? (Future work)

# Outline

- Model Set up
- Model Validation
- With and without causeway comparisons
  - Circulation
  - Simplistic views of residence times
  - Temperature

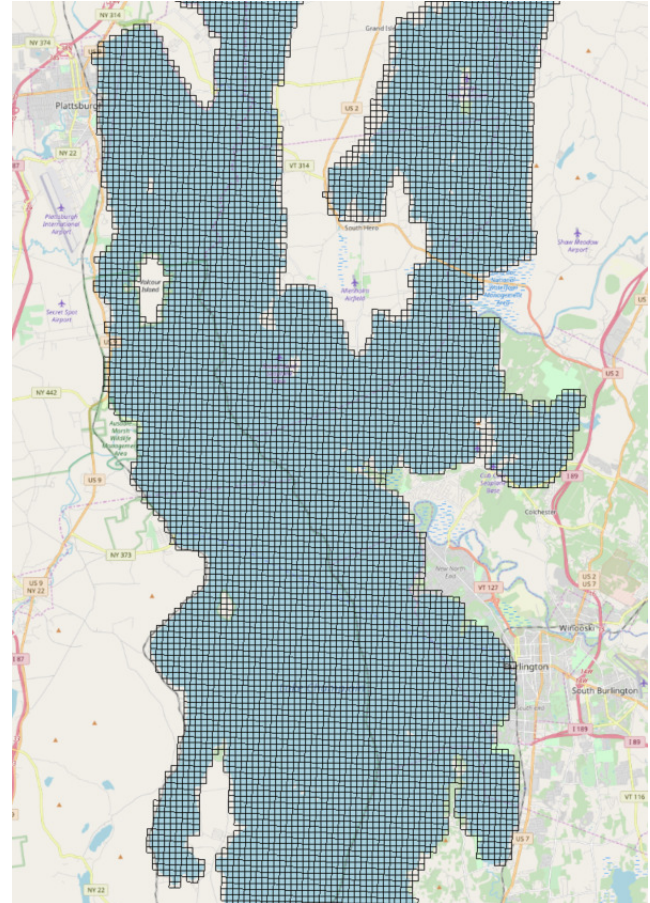


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# Model set up: DFLOW-Flexible Mesh

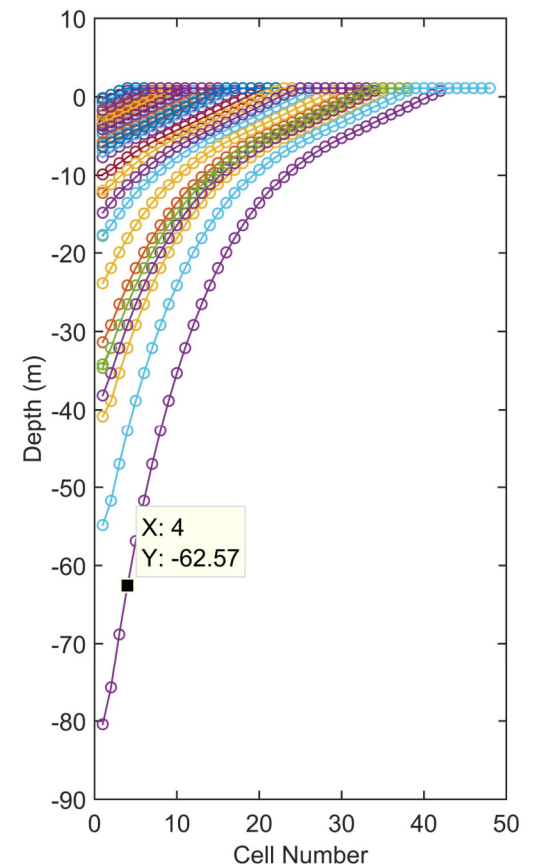
- 22,254 cells with 300 m horizontal resolution and cut cells at boundary
- Vertical resolution of 0.5m in top 6 meters, cells stretched to the bottom
- Discharge boundaries use USGS gage information with flows modified based on GIS area weighting
- Wind forcing based on spatial interpolation of available meteo stations (2 to 6 depending on timeframe)
- Humidity, Air Temperature, and Solar Radiation applied spatially uniform average of available data
- Outflow through Richelieu River controlled by weir



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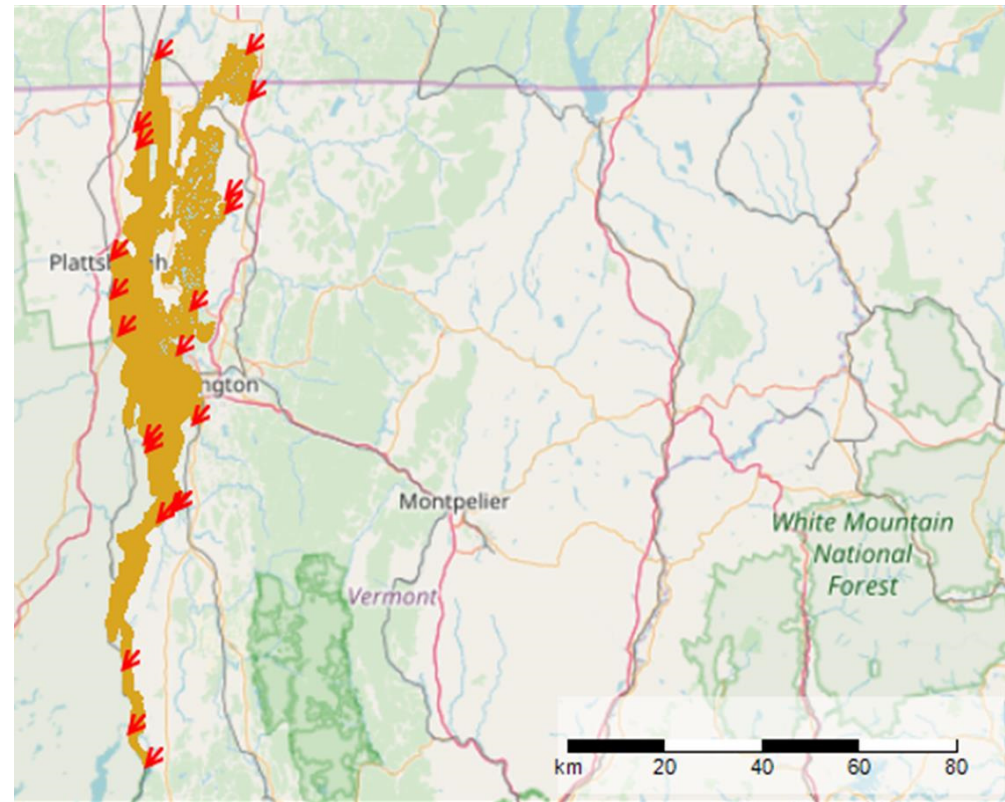
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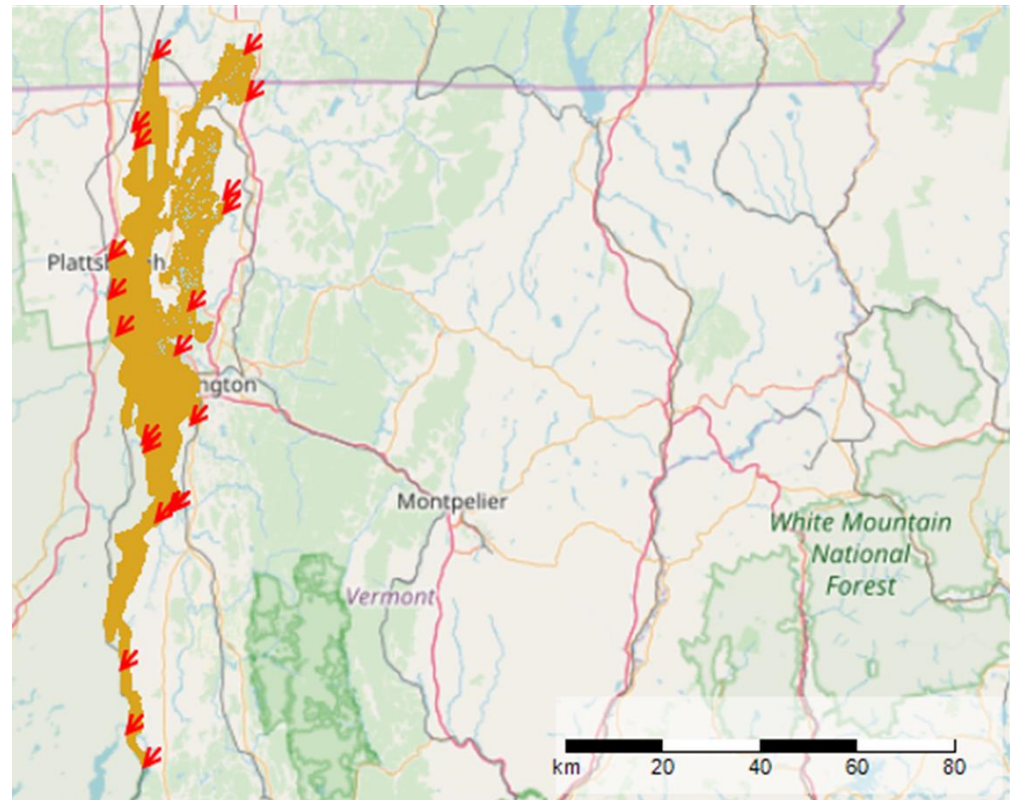
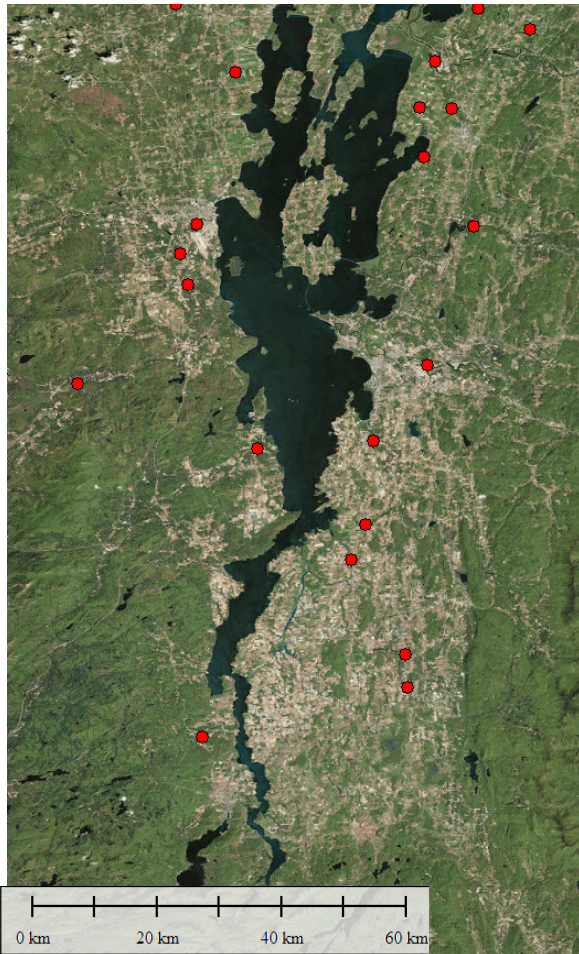
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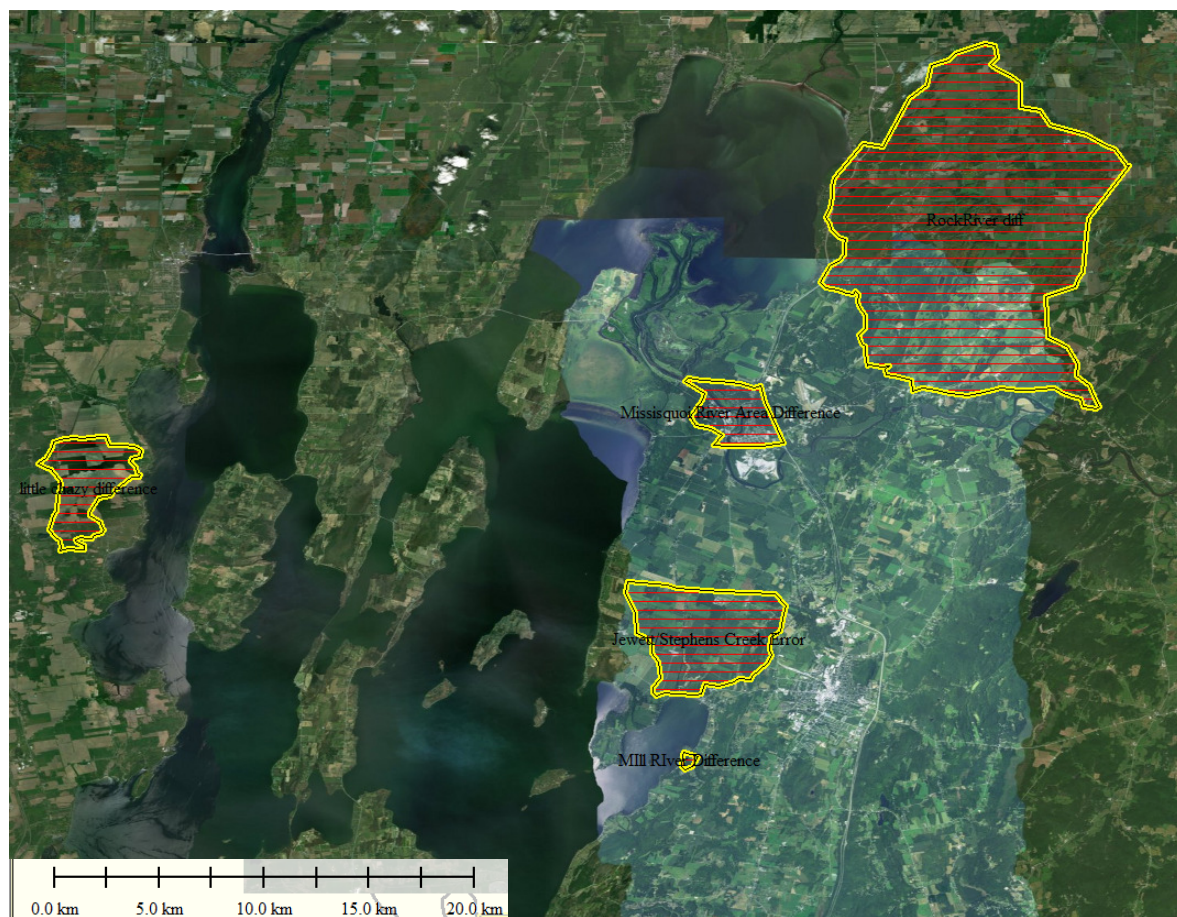
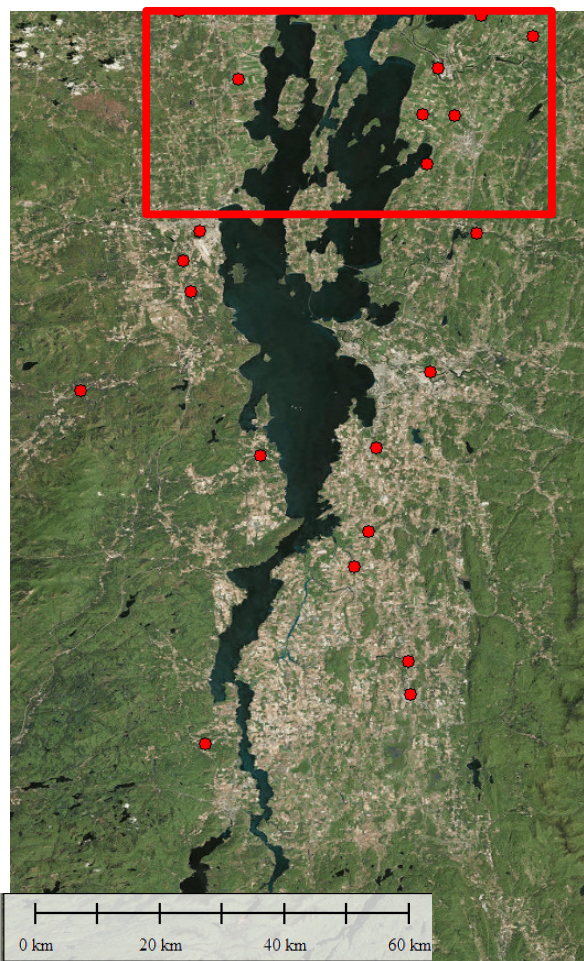
# Location of River Gages in the Champlain Basin



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# River Gages are not located at model boundary!



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# Simple Hydrology Model

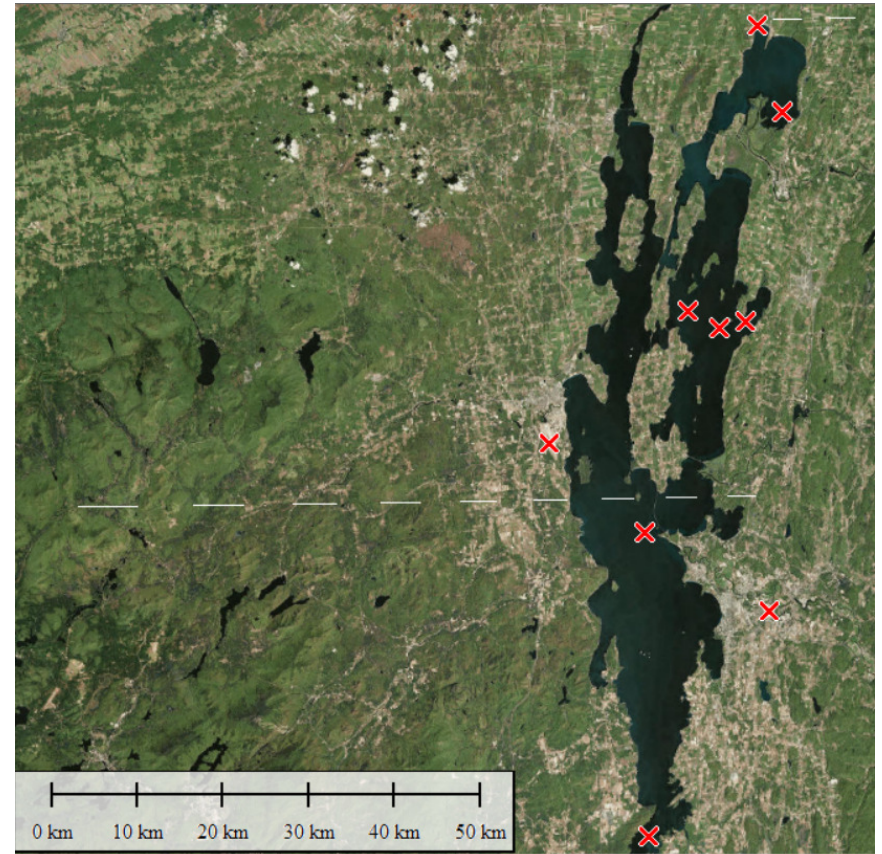
$$Q_{model} = F_{geo} \times Q_{measured}$$

$$T_{river} = \max\{0.6 \times T_{air}, 0\}$$



# Model set up: DFLOW-Flexible Mesh

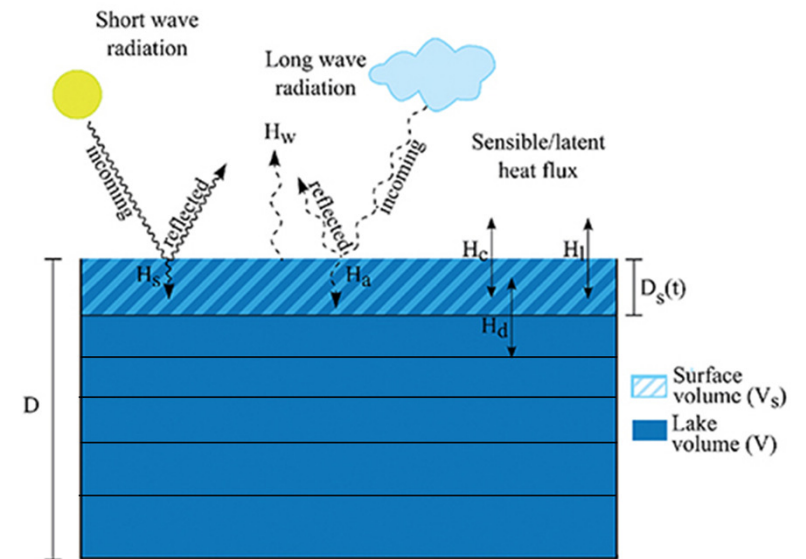
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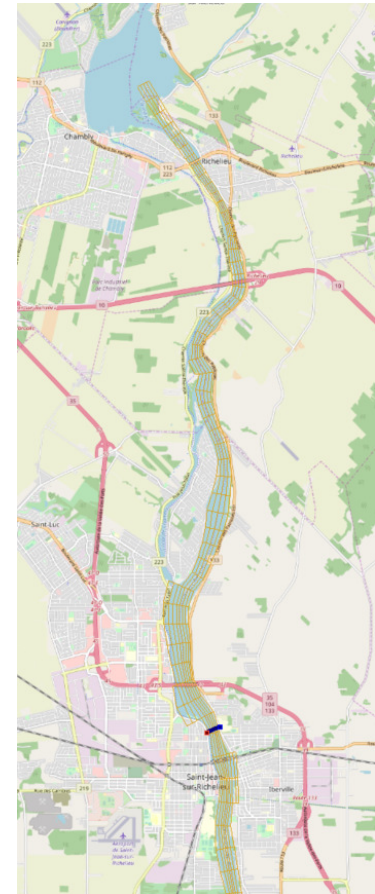
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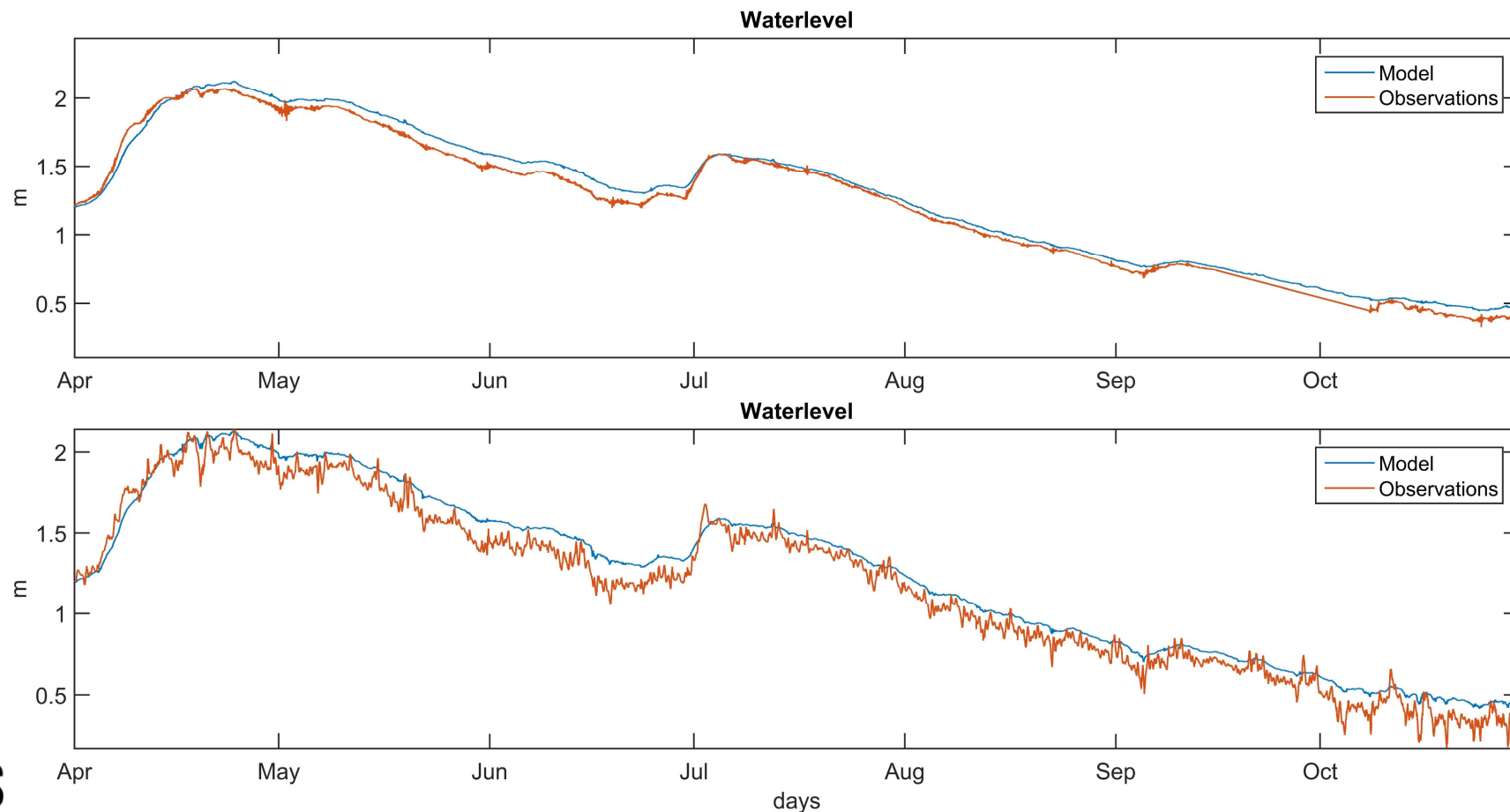
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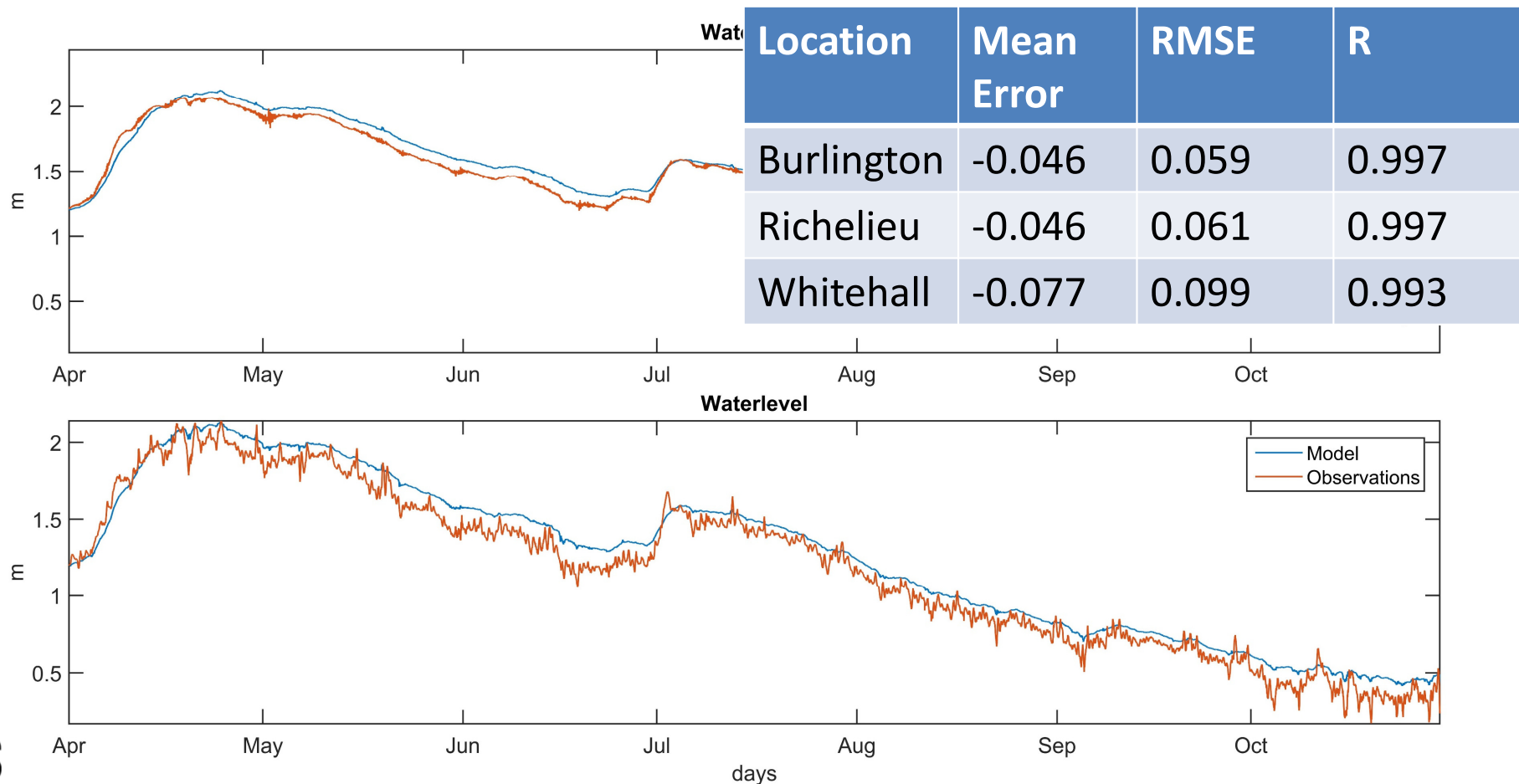
Preliminary Information-Subject to Revision. Not for Citation or Distribution.



# Model Validation: Waterlevel

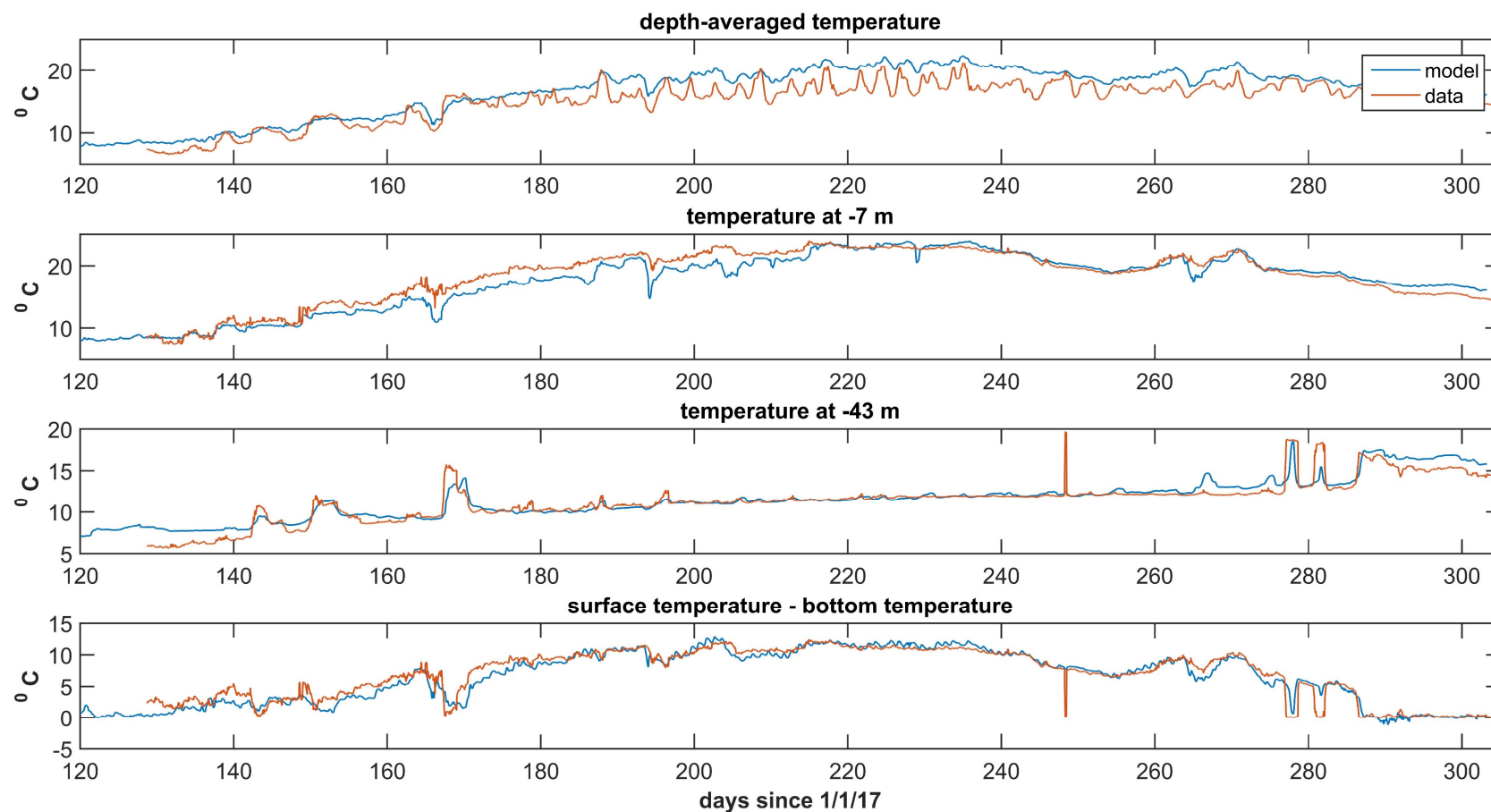


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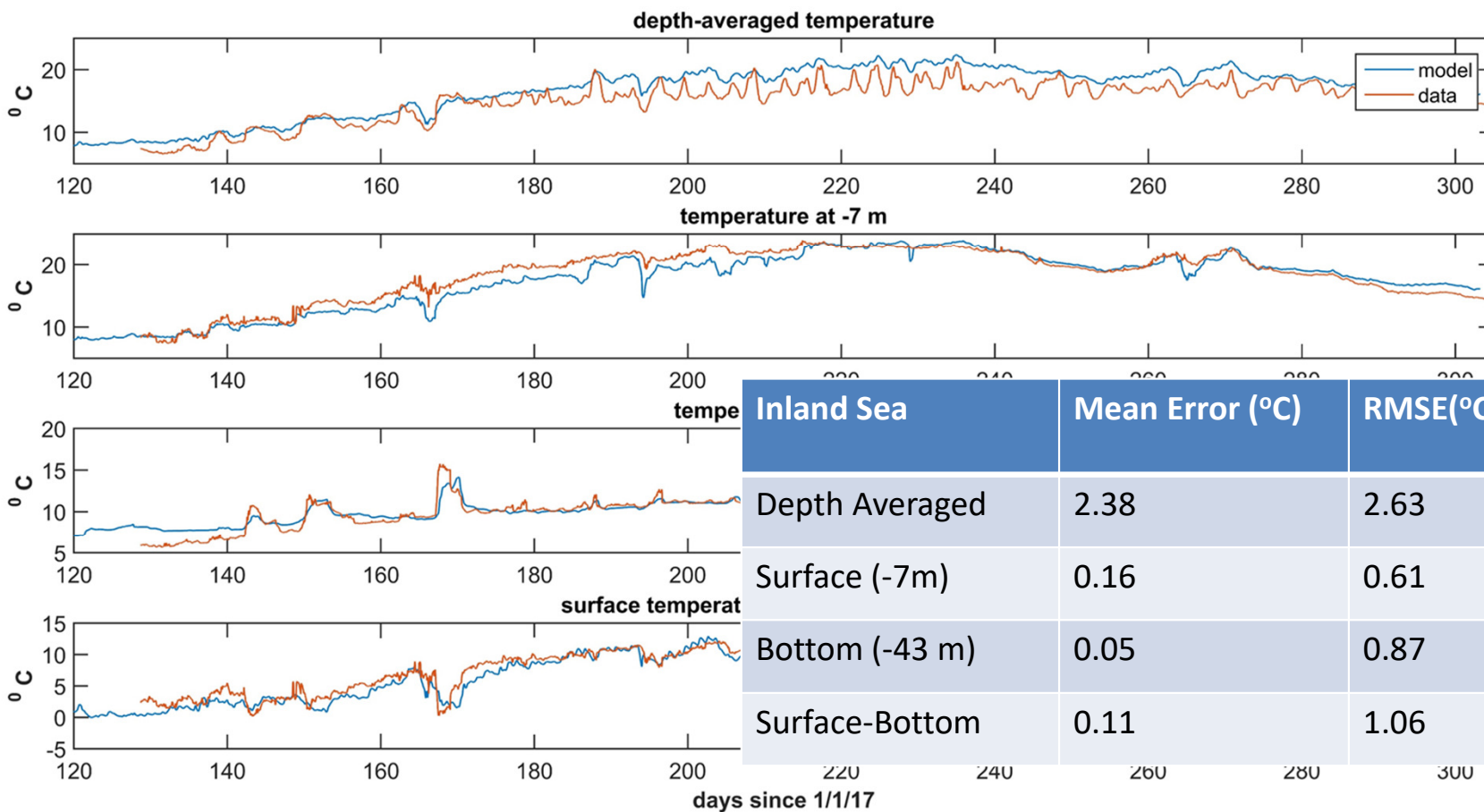


Preliminary Information-Subject to Revision. Not for Citation or Distribution.

# Model Validation: Temperature



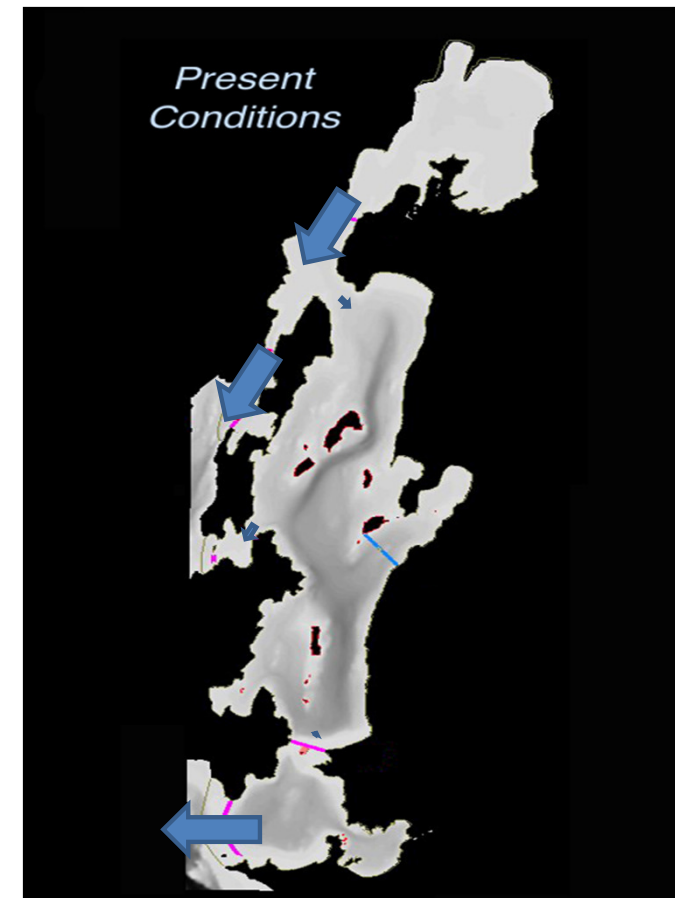
# Model Validation: Temperature



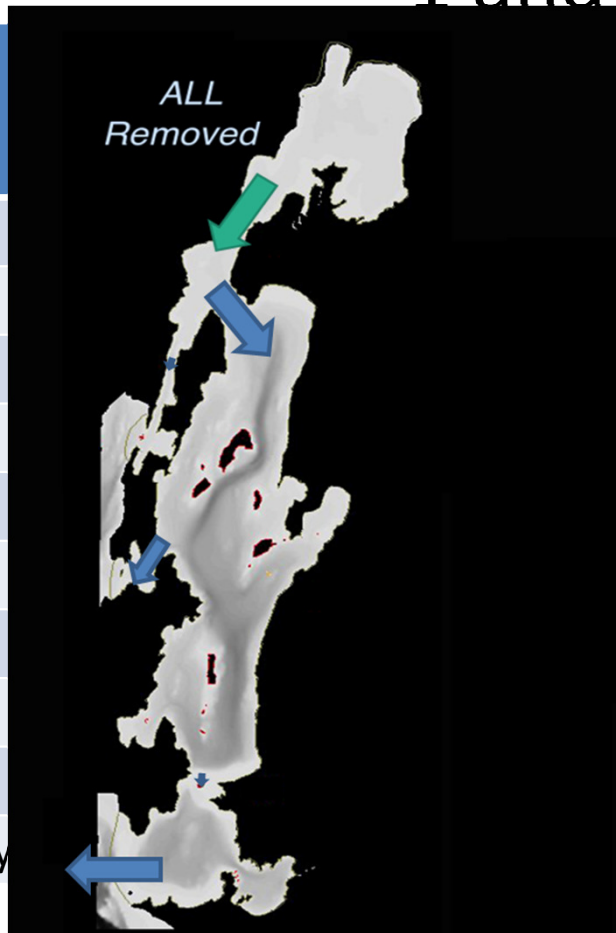
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# Cumulative Discharge Changes between April 1 and Nov 1 2017

Cross Section Location	Causeway Discharge by Nov 1 ( $10^9 \text{ m}^3/\text{s}$ )	
Fryers Dam	8.194	100%
Burlington	2.319	29%
Crown Point	1.006	12%
Missisquoi Bay	1.153	14%
Allburg Bridge	1.1	13%
Inland Sea North	0.067	1%
Carry bay	1.1	13%
Gut	0.273	3%
SandBar	-0.0243	0.2%
Outer Mallets Bay	0.923	11%



# Cumulative Discharge Changes between April 1 and Nov 1 2017



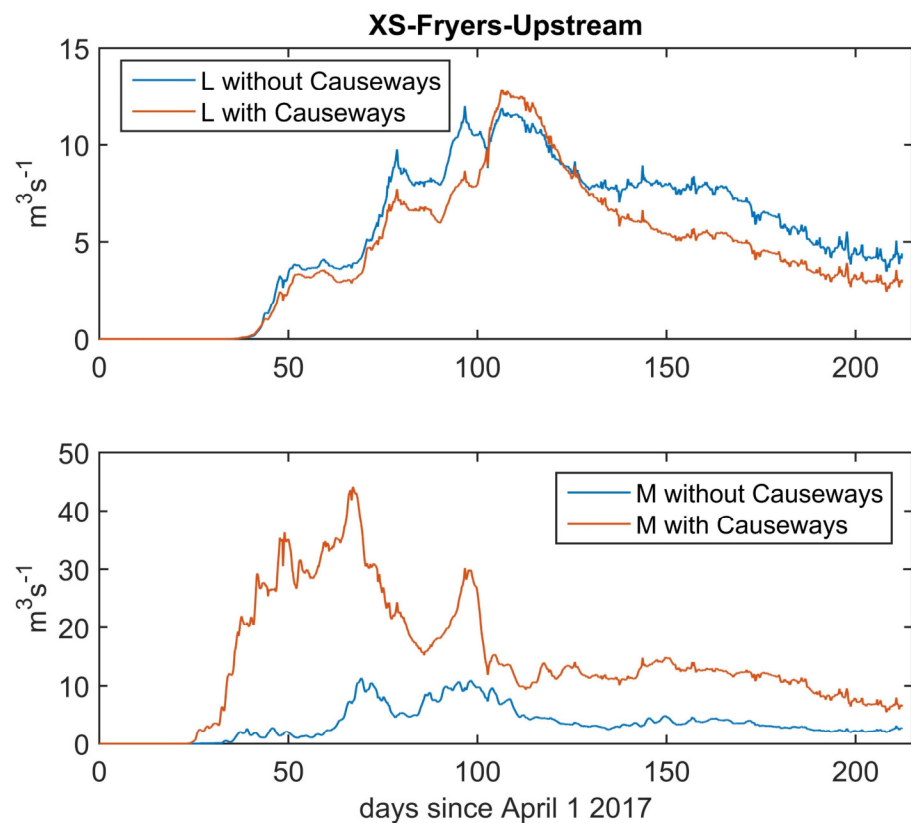
Causeway Discharge by Nov 1 ( $10^9 \text{ m}^3/\text{s}$ )		% Total difference
8.194	100%	<0.1 %
2.319	29%	<0.1 %
1.006	12%	<0.1 %
1.153	14%	0.1 %
1.1	13%	13%
0.067	1%	16%
1.1	13%	8%
0.273	3%	6%
-0.0243	0.2%	1.7%
0.923	11%	2%



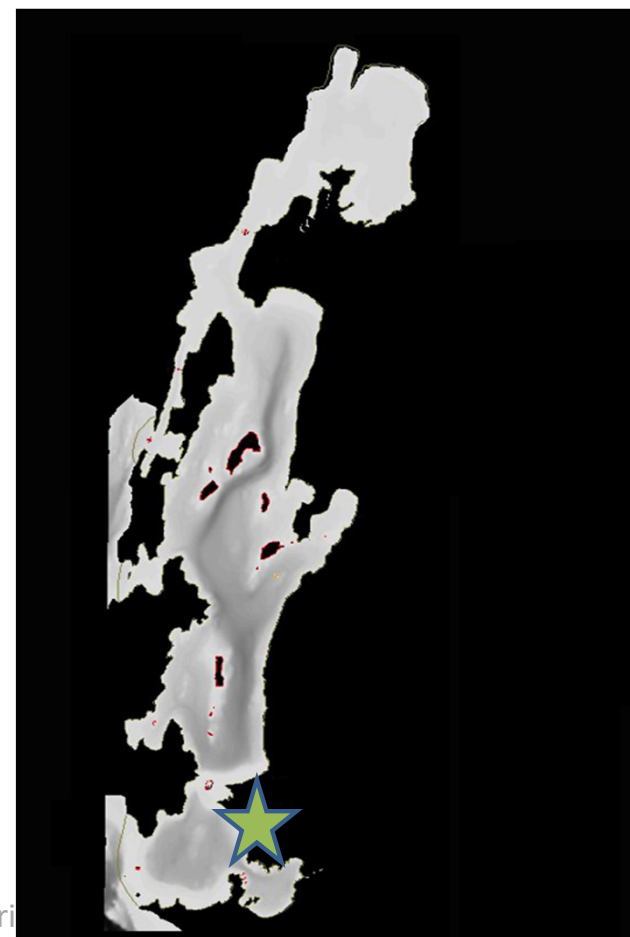
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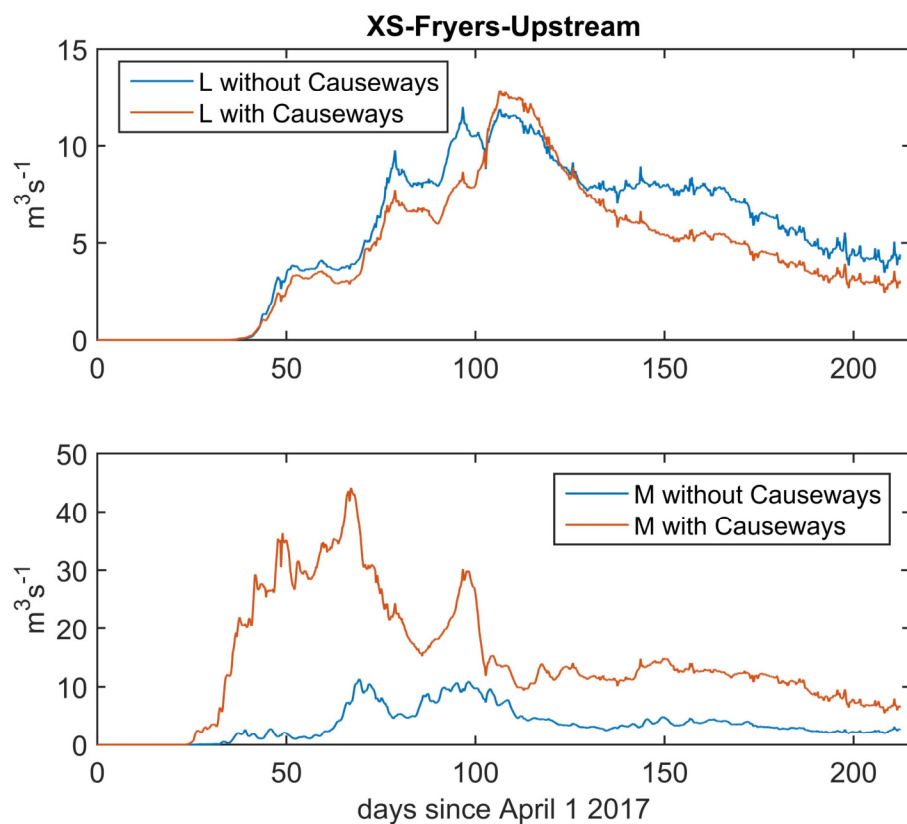
# Residence Time Changes: Depends on where you start



Water from Lamoille river exits at close to the same time and rate whether the causeways are altered or not

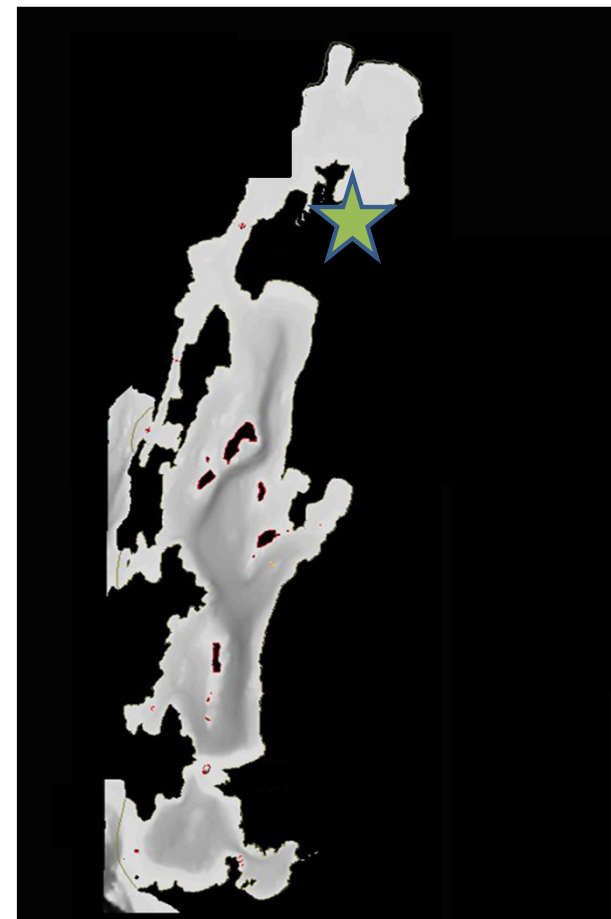


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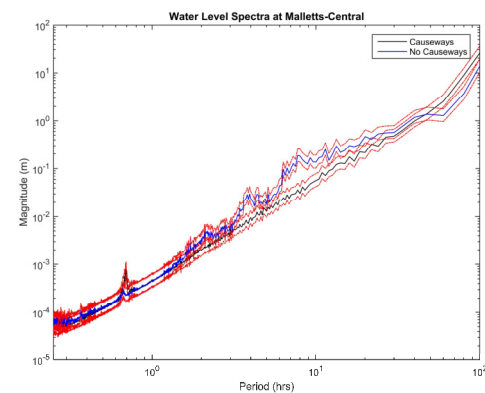
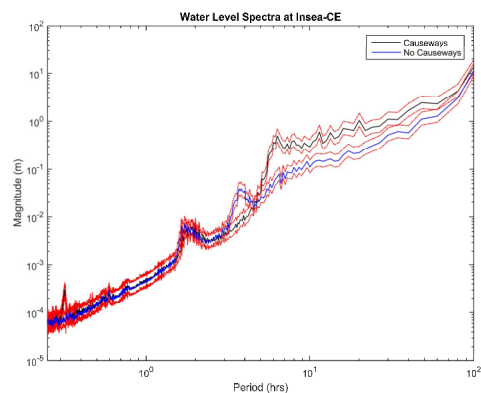
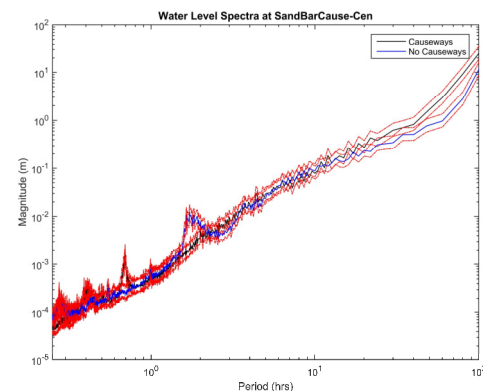
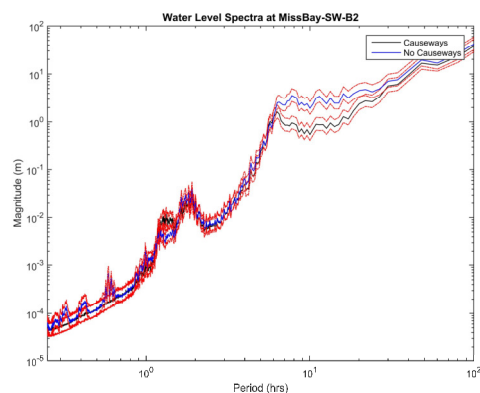


Water from Lamoille river exits at close to the same time and rate whether the causeways are altered or not

Water from the Missisquoi River passes through the lake system much more rapidly in the presence of causeways!

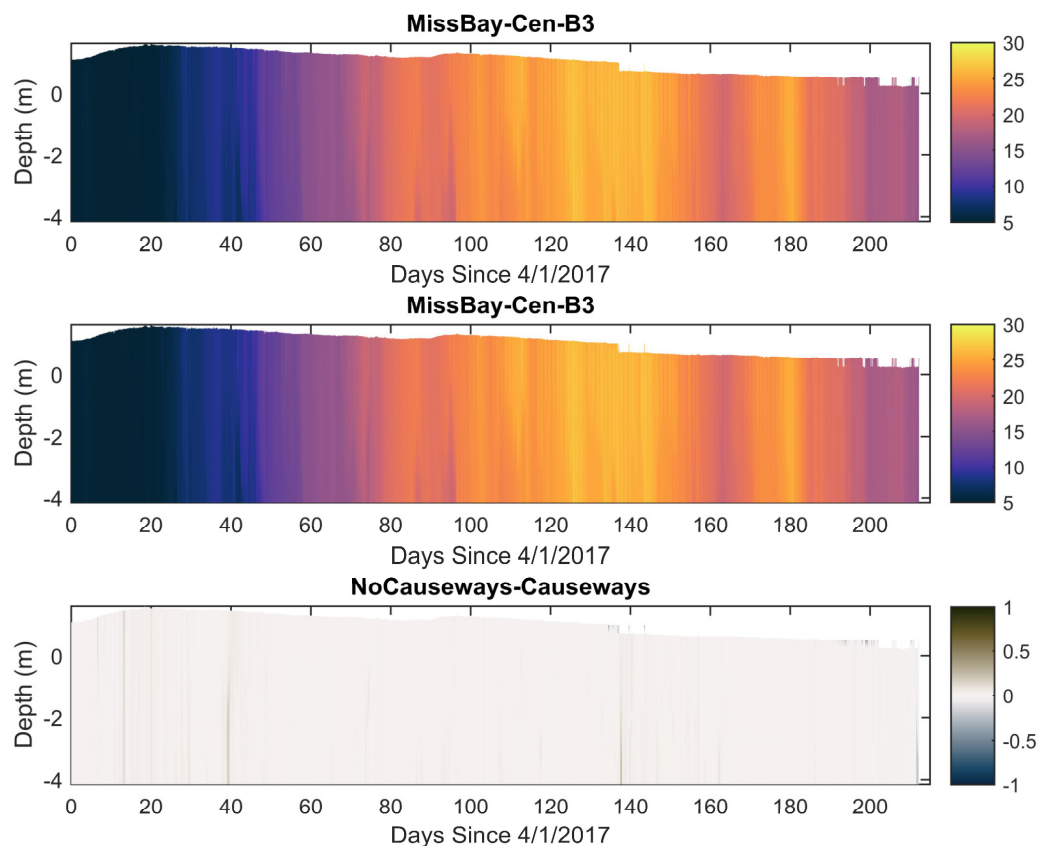


# We have also observed a difference in water level spectra upon the removal of causeways

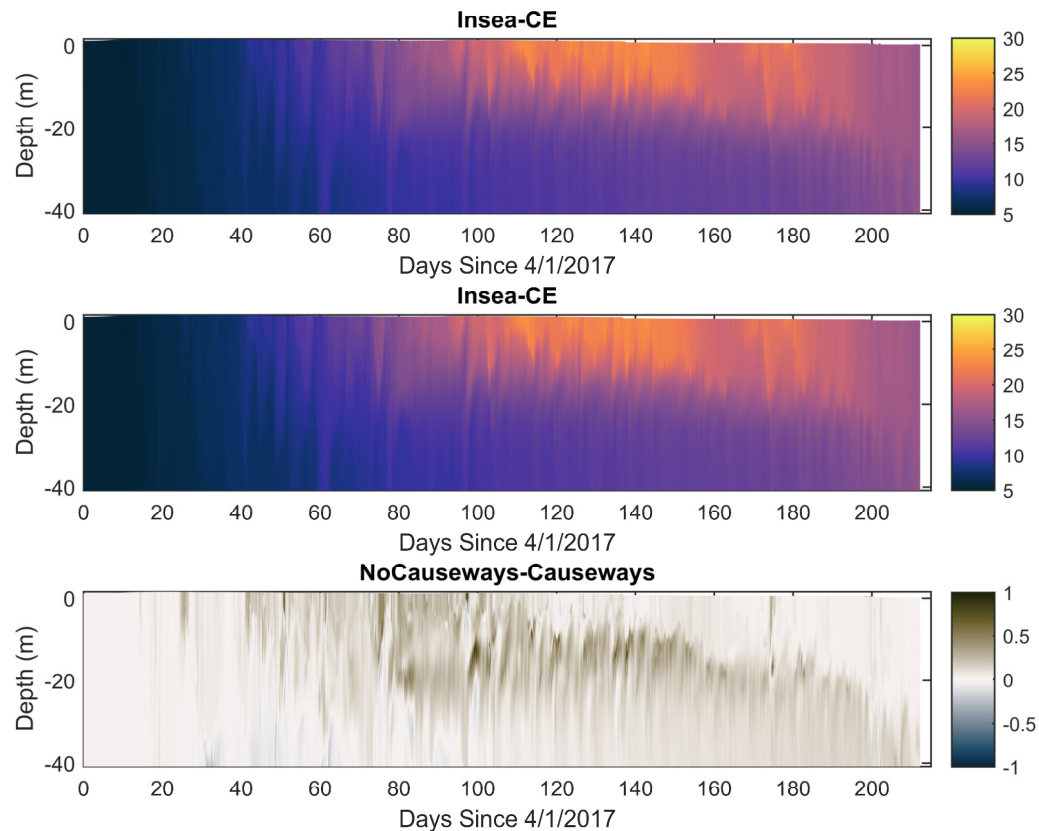


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Temperature Changes: some slightly different vertical structures but not strongly warmer or colder overall

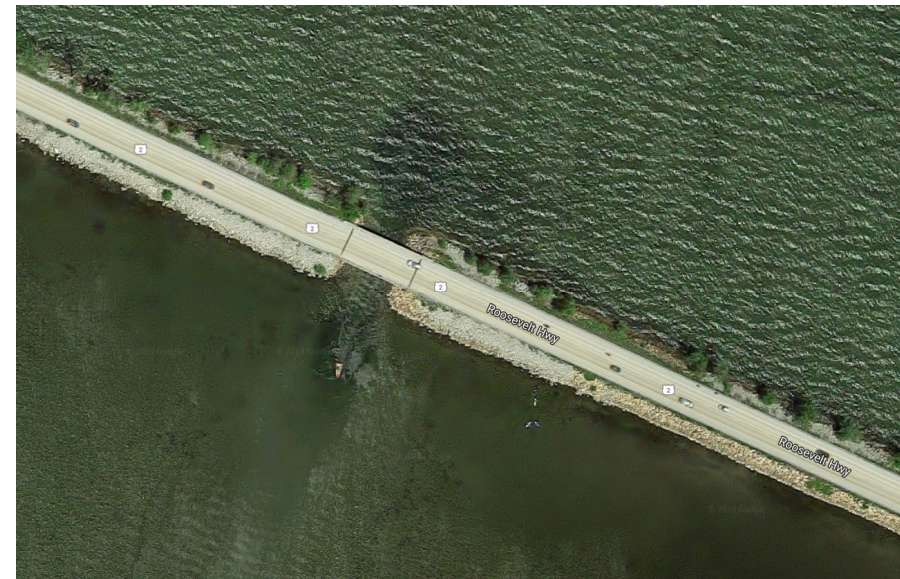


# Temperature Changes: some slightly different vertical structures but not strongly warmer or colder overall



# Conclusions and Future Work

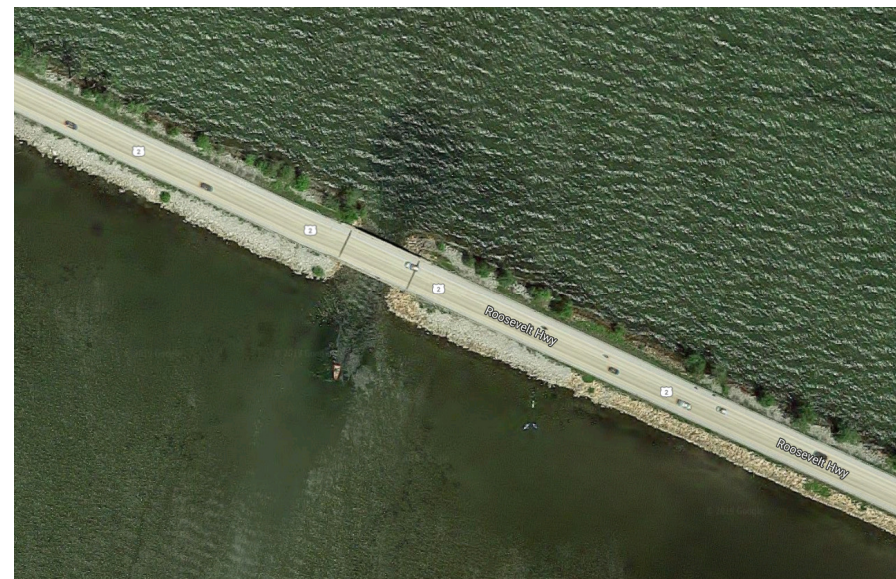
- The overall lake circulation pattern is changed by causeway removal, with the change varying by location and season.
- There is evidence of shorter period (~10 hour) surface oscillations being modified by the presence of causeways.
- Further investigation is required to understand the cause and possible impacts of temperature changes
- Changes in sediment delivery and deposition may be different due to the causeways, incorporating that change may enhance the observed differences.





# Thank You

For more information contact  
Liv Herdman at the New York  
Water Science Center  
[lherdman@usgs.gov](mailto:lherdman@usgs.gov)



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